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WIND EROSION AS AFFECTED BY REDUCED TILLAGE SYSTEMS 1/

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Abstract

The "cardinal" or "golden" rule of wind-erosion control is to keep the land surface covered with vegetation or vegetative residue. A secondary rule is to maintain as rough and cloddy a surface as is compatible with crop production. Reduced tillage is a practical means of implementing these rules. To emphasize the importance of wind-erosion control, this paper considers the effects of wind erosion on the quality of the environment, discusses the principles of control and the requirements of tillage for control, and reviews existing data on the effectiveness of reduced tillage of both row crops and small grains in reducing wind erosion. The data demonstrate that both reduced tillage and judicious selection of kinds of tillage machines can substantially reduce the land's susceptibility to wind erosion.

Wind Erosion and Environmental Quality

According to the 1965 National Inventory of Soil and Water Conservation Needs (4), wind erosion is the dominant problem on about 70 million acres of land in the United States--55 million acres of cropland, 9 million acres of rangeland, and 6 million acres of "other" land. Normal good farming practices adequately protect about 34 percent of this land, so special wind erosion control practices are needed on about 46 million acres. Wind erosion is most serious in the Great Plains, but it also occurs in the Pacific Northwest and Southeastern Coastal Areas, along the Eastern Seaboard, and around the Great Lakes.

Damage from wind erosion over the past 35 years has ranged from 1 to 16 million acres, averaging about 5 million acres for the past 20 years. Wind erosion affects the quality of our environment in many ways. It (a) ruins fields by removing silt, clay, and organic matter from the soil surface; (b) reduces crop yield by removing fertility and destroying favorable soil physical conditions; (c) damages vegetables, cotton, corn, sugar beets, and other crops by abrasion, resulting in reduced yields and marketability or crop destruction; and (d) pollutes the air. Measurements in duststorms have shown particulate concentrations of from 675 to 280,000 micrograms per cubic meter, which far exceeds the 80 micrograms per cubic meter considered tolerable for good quality air. The most commonly used estimate of wind erosion's contribution to the atmospheric particulate load is 30 million tons per year (22). However, recent analyses of Great Plains dustload data indicate a much larger area is involved when duststorms are active than had been considered--about 188 square miles--and that

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dustloads averaged 244 and 77 million tons per year in the 1950's and 1960's, respectively (11). Public concern for environmental quality has generated considerable activity in developing standards to regulate emission of pollutants into the atmosphere. Iowa and Kansas now have regulations that could be applied to erosion of soil by wind. Other states are working on similar standards. Hence, it is imperative that we use all available means, including reduced tillage, to control wind erosion.

Principles of Wind Erosion Control

Five principles of wind-erosion control can be established from analyses of wind-erosion phenomena: (a) establish and maintain vegetative or nonvegetative land covers; (b) reduce field lengths along the prevailing wind direction; (c) produce stable clods or aggregates on the land surface; (d) roughen the land; and (e) level or bench land, where economically feasible, to reduce field widths affected and erosion rates on slopes and hilltops, where converging streamlines of windflow cause increased velocity and shear stress (27).

Tillage System Requirements to Control Wind Erosion

Tillage has direct bearing on wind-erosion control principles a, c, and d, i.e., for effective control, tillage must leave crop residues on the land, yet maintain as rough and cloddy a soil surface as is compatible with good seed germination and crop production. Requirements for residues, cloddiness, and roughness vary, depending on the influence of those variables not only on each other but also on two additional variables, climate and field width. The relationship among all five variables and the amount of wind erosion that will occur is expressed by the equation: $E = f(I', K', C', L', V)$ where E is amount of erosion in tons per acre, I' is the soil erodibility index measured in terms of soil cloddiness greater than 0.84 mm. in diameter, C' is the climatic factor measured in terms of wind velocity and surface soil moisture, K' is soil surface roughness, L' is unsheltered field width, and V is vegetative cover (3, 17, 18, 24).

Figure 1 shows how different amounts of small grain and sorghum residue in the Great Plains and corn and soybean residue in the Corn Belt affect wind erosion. Figures 2 and 3 show, respectively, the influence of soil cloddiness and of surface roughness on wind erosion in fields located in those two climatic areas. If tolerable erosion is considered to be 5 tons per acre or less, then substantial amounts of residue and high degrees of cloddiness and roughness are required to control wind erosion. Because tillage tends to decrease the quantity of all three variables, the importance of reducing it cannot be overemphasized.

Effects of Tillage Systems on Wind Erosion

Though direct effects of reduced tillage on wind erosion have not been researched extensively, a number of investigators have evaluated the residue-conservation and clod-producing characteristics of different machines and the sequences of operation commonly used in producing both small grains and row crops. Some of those results will be summarized here.

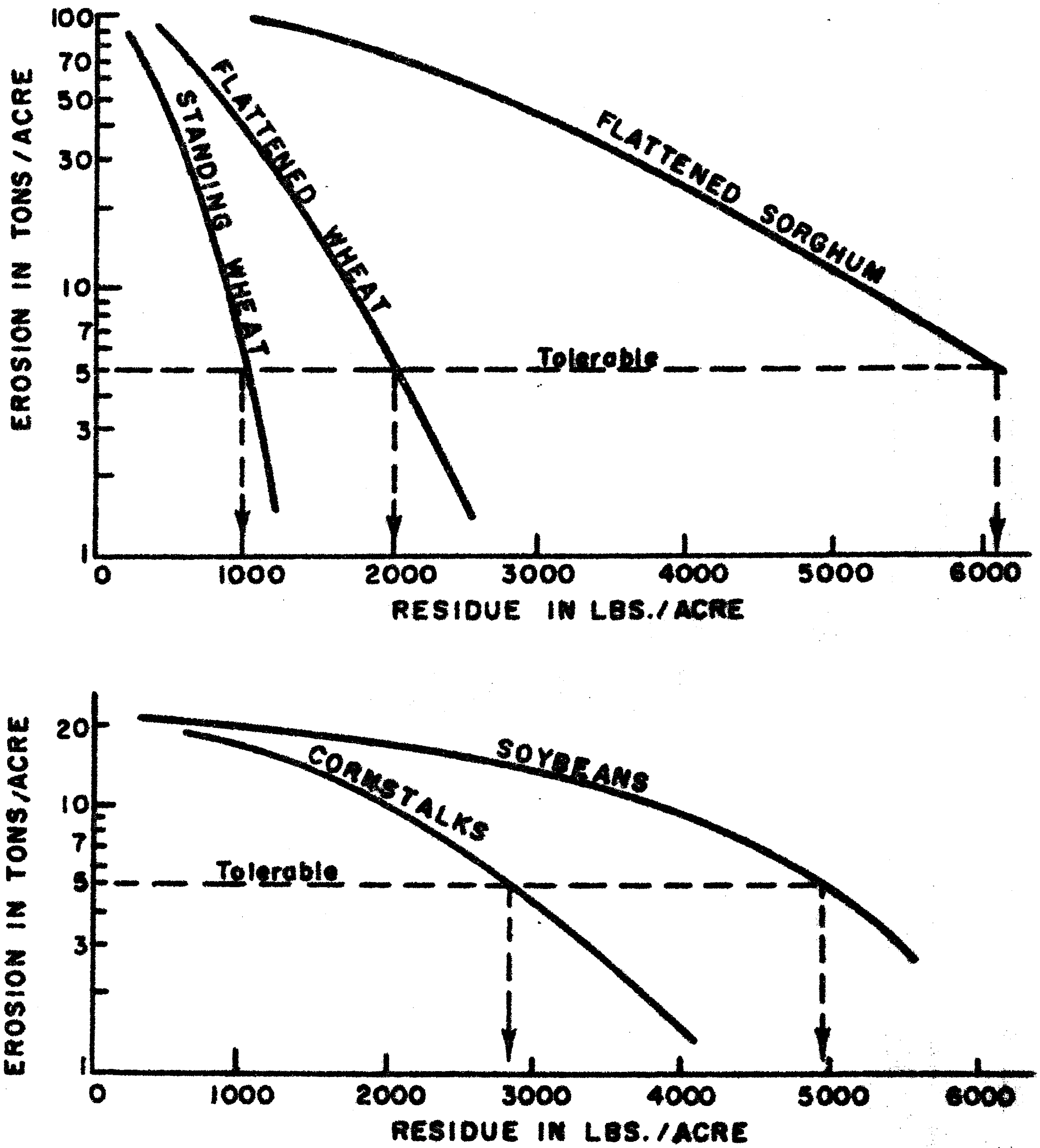

Figure 1.--Effects of small grain, sorghum, soybean, and cornstalk residue on soil erosion by wind. Small grain and sorghum computed for Dodge City, Kansas, area in March from wind erosion equation (17) where $C' = 100$, $I' = 120$, $K' = 1.0$, $L' = 660$ feet, $A = 0^{\circ}$, $R_m = 2.4$, $K_{50} = 1.15$, and $D_{50} = 760$ feet. Soybean and cornstalks computed for La Crosse, Wisconsin, area in March; $C' = 20$, $I' = 120$, $K' = 1.0$, $L' = 660$ feet, $A = 45^{\circ}$, $R_m = 1.8$, $K_{50} = 1.8$, and $D_{50} = 1{,}190$ feet.

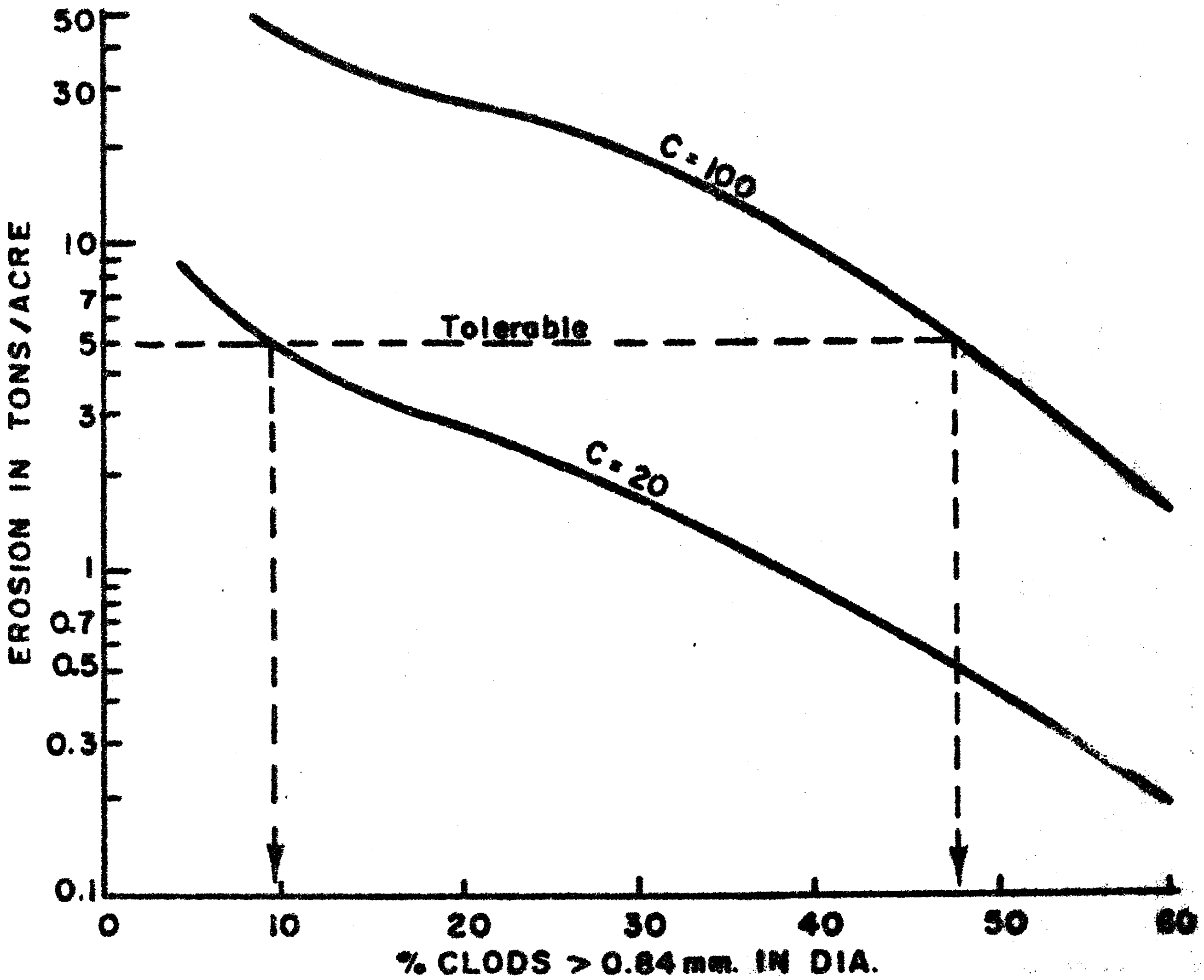

Figure 2.--Effect of soil cloddiness on wind erosion. Computed from wind erosion equation (17) using 1,000 pounds per acre of residue and same values of other variables as in figure 1.

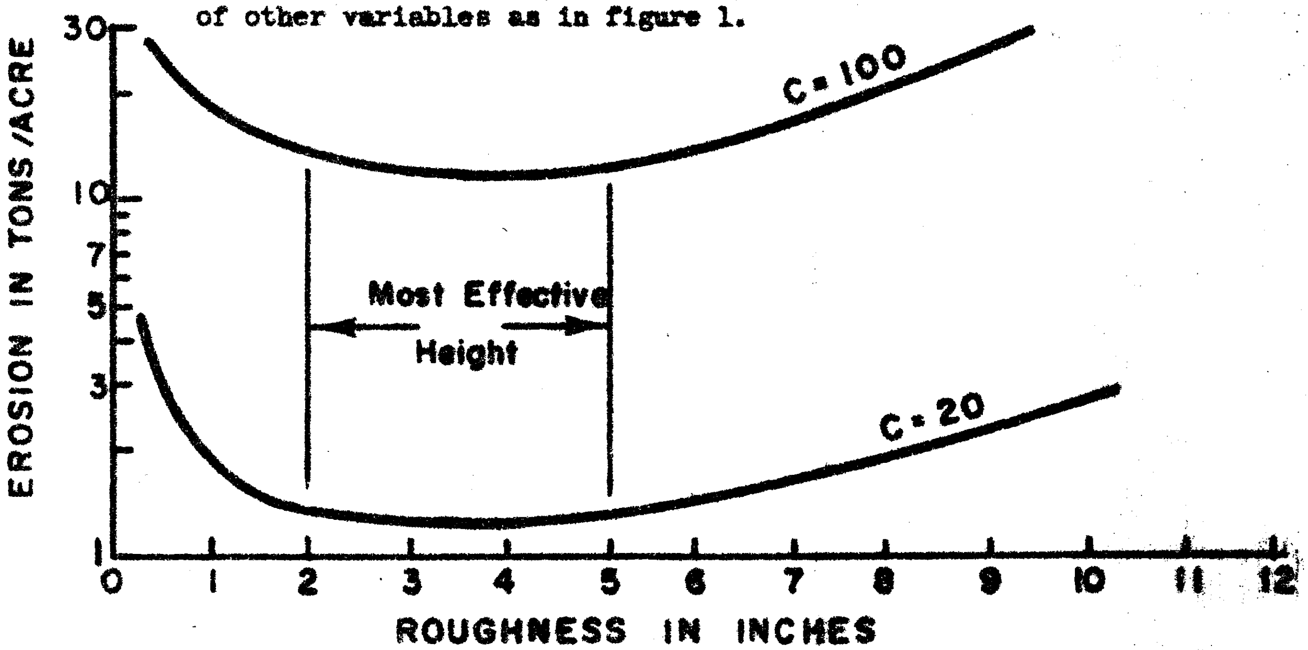

Figure 3.--Effect of surface roughness on wind erosion. Computed from wind erosion equation (17) using 1,000 pounds per acre of residue and same values of other variables as in figure 1.

Small Grains

Table 1 presents a composite of results from various investigators who have evaluated the residue-conservation characteristics of machines commonly used in stubble mulching for wheat production in the Plains. The wide ranges given for the various implements are due to factors relating to the residue itself such as height and length of stubble, amount of pretillage residue during initial operations, and previous positioning or orientation of residue; and to factors relating to the implements such as speed and depth of operation, angle and concavity of disks, and width, pitch, and angle of sweep blades. Those factors were taken into account in computing quantity of residue, cloddiness, and potential wind erodibility of two different commonly used sequences of tillage (table 2). Soil mixing implements such as the one-way destroy far more residue than do subsurface sweeps; therefore, one must conclude that reduced tillage action as well as reduced numbers of tillage operations reduces wind erosion.

Table 1.--Residue maintained with tillage implements.*

Type of implement	Average maintained after each tillage operation	Range maintained**
	%	%
Subsurface implements:		
Blades (36" or wider)	90	70 to 113
Sweeps (24" to 36")	90	60 to 112
Rodweeders - plain rod	90	80 to 115
Rodweeders - with semichisels	85	55 to 105
Mixing implements:		
Heavy-duty cultivator (16" to 18" sweeps)	80	50 to 100
Heavy-duty cultivator (2" chisels 12" apart)	75	-------
One-way disk (24" to 26" pans)	50	30 to 90
Tandem or offset disks	50	-------

* Data from Anderson (1, 2), Woodruff and Chepil (23), Fenster (7), and Woodruff et al. (25).

** Maintenance values greater than 100 percent mean that more residue was brought to the surface than was buried.

Fenster and McCalla (9), in an 8-year study in western Nebraska, evaluated the effects of subtill stubble mulching, one-way disking, and moldboard plowing on wind erodibility in a wheat-fallow rotation. The plowed plots were cultivated with rotary hoe, spring-tooth harrow, and rodweeder; the one-way plots were cultivated several times with V-sweep and rodweeder; and the subtilled plots received three operations with the large V-sweep, then several with a rodweeder. Average results for the 8 years showed wind erodibilities of 0.86, 1.40, and 2.94 tons per acre for subtill, one-way, and plowed plots, respectively. During 2 years out of 8, soil losses from the plowed plots amounted to 5.7 and 10.1 tons per acre, thus exceeding the 5-ton-per-acre tolerable limit. In no year did soil loss from one-way disk or subtill treatments exceed the tolerable.

Table 2.--Effect of two commonly used summer-fallow tillage sequences on quantity of wheat residue conserved, soil cloddiness, and potential wind erodibility.*

Tillage sequence		Residue remaining after operation		Clods > 0.84 mm. in diameter	Potential wind erodibility
Operation	Machine used	%	Lbs./acre	%	Tons/acre
0	Pretillage	100	2,000	----- nonerodible -----	
1	8-foot V-sweep	86	1,720	65	0.10
2	32-inch sweeps	74	1,480	60	0.45
3	Rodweeder	63	1,260	58	0.88
4	Rodweeder	53	1,070	57	3.70
0	Pretillage	100	2,000	----- nonerodible -----	
1	One-way	57	1,140	71	0.40
2	One-way	40	800	67	3.20
3	32-inch sweeps	44	880	66	2.75
4	Rodweeder	37	750	64	4.50

* Tillage data from Fenster et al. (8) and Woodruff et al. (25, 26). Wind erodibility computed with the wind erosion equation (24) using indicated cloddiness and residue with a C' of 100, a K' of 1.0, and a field length L' of 2,640 feet.

Chepil and Woodruff[3/], who conducted portable wind-tunnel tests on a number of winter wheat fields in the Nebraska Panhandle, found that fields that had been "clean" or "black" fallowed with the moldboard plow (leaving 610 pounds of residue per acre) had average erosion losses of 10.7 tons per acre but stubble-mulched fields (with 2,620 pounds of surface residue per acre) had erosion losses of only 0.8 ton per acre. Those data show the advantages of subtillage implements over mixing-type implements for controlling wind erosion. However, during dry years initial residues may be so sparse that even subtillage, if carried out enough times to provide adequate weed control, will reduce residue quantities to amounts insufficient to protect succeeding crops from wind erosion. Methods to reduce the number of tillage operations, to eliminate mechanical destruction, are therefore needed.

Unger (20) and Unger, Allen, and Wiese (21) at Bushland, Texas, evaluated, respectively, a delayed fallow concept and the use of herbicides to reduce number of tillage operations, conserve residue, and to aid in conserving water and controlling wind erosion. Delayed fallow (no tillage after crop harvest until weed growth commences the following spring) was compared with one-way, stubble-mulch, and field cultivator-tillage; six operations were completed on the delay fallow and ten on the other treatments. Wind tunnel tests, run when the land was in fallow, showed that soil losses from the delayed fallow about equalled those from field cultivator tillage but were about 1/3 of those from stubble-mulch and only about 1/20 of those from one-way tillage. Tests run when the land was in wheat showed that in very early stages of growth, soil losses from the delayed fallow about equalled those from one-way tillage but were about 1/3 of those from stubble-mulch and only 1/20 of those from field cultivator tillage. Wind erodibility of the plots treated with herbicides was not measured directly; however, plots treated only with atrazine and 2,4-D at 3.0 and 1.0 pounds per acre, respectively, and those receiving one sweep operation plus herbicides had 4,100 and 4,000 pounds per acre of residue as compared with 200, 1,000, and 3,200 pounds per acre for tandem disk, disk and sweep, and sweep-alone tillage treatments, respectively. Unger et al. also reported substantial advantages in soil water storage for the herbicide treatments over tillage treatments; weed control for both treatments involving herbicides was 100 percent.

Table 3 shows some results from preliminary investigations of the effects of reduced tillage and herbicides on residues, wind erodibility, soil water, and wheat yield obtained by Woodruff and Harris at Colby, Kansas[4/]. In those experiments substantial quantities of residue were conserved, which provided good wind-erosion control; but because of ineffective weed control, excessive soil water was used, which drastically reduced wheat yields. Those negative results emphasize that weeds must be controlled if reduced tillage is to accomplish good wind-erosion control and at the same time produce a profitable crop.

Row Crops

Tillage machine effects on conserving row crop residue have not been studied so extensively as those on small grain residue. At Akron, Colorado, (10) and Manhattan, Kansas, (19) the effect of fall as opposed to spring tillage of sorghum

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3/ 1957 Annual Report, Manhattan, Kansas.

4/ 1965 Annual Report, Manhattan, Kansas.

Table 3.--Effects of experimental minimum or skip-tillage summer-fallow treatments on residue conservation, soil cloddiness, water use, crop yield, and wind erodibility.**

Tillage sequence++	Amount of residue retained at end of tillage season	Clods > 0.84 mm. in diameter	Potential wind erodibility	Soil water loss during tillage season	Wheat yield
	Lbs./acre	%	Tons/acre	Inches	Bu./acre
N-*-*-(M + TD)	1,140	58	2.0	4.9	3.5
OW-*-*-(M + TD)	1,090	54	4.0	4.8	3.9
S-Chemical fallow‡	2,230	65	0.02	2.8	6.6
OW-OW-*-MR	804	50	13.0	2.1	20.8
N-S-RW-RW	900	51	7.5	1.2	25.3
OW-S-RW-RW	520	58	12.5	1.0	29.7

++ N, 8-foot V-sweep; *, skip operation, no tillage; M, rotary mower; TD, tandem disk; OW, one-way disk; S, 30-inch V-sweeps, MR, rodweeder with chisels; RW, plain rodweeder.

‡ 2,4-D (2,4-dichlorophenolyacetic acid) applied at rate of 1/2 pound ester per acre.

** Data from Woodruff and Harris, 1965 Annual Report, Manhattan, Kansas. Wind erodibility computed with the wind erosion equation (24) using indicated cloddiness and residue with C' of 100, a K' of 1.0, and field length L' of 2,640 feet.

residue was investigated. The Colorado studies showed no advantage and many disadvantages for fall tillage in areas where wind erosion was critical. However, the Kansas studies showed that fall disking of sorghum stubble increased stands and grain yields. The Colorado investigation (in which one-way, sweeps, tandem disk, and rodweeder with shovels were used in five sequences to accomplish four operations during the tillage season) showed that amounts of sorghum residue were reduced by 17 to 45 percent, about equal to the 31 to 34 percent reduction caused by winter weathering. But only about 860 pounds per acre of residue was available at the beginning of tillage; so the 150 to 400 pounds per acre remaining after tillage was far short of that required to control wind erosion.

Schmidt and Triplett (15) and Schmidt and Kroetz (16) reported substantial benefits for wind erosion control, using reduced tillage systems in northwestern Ohio. During a severe windstorm, 130 tons per acre of soil were lost from a plowed-planted cornfield, but only 2 tons per acre were lost from a no-tillage-planted cornfield on which preemergent applications of atrazine, simazine, and 2,4-D were used to control weeds (15). Schmidt and Kroetz reported the results shown in table 4 for two sets of experiments conducted with cornstalk residue on Ottokee loamy fine sand at the OARDC Sand Farm in Wood County, Ohio, in 1968. Concluding that no tillage or reduced tillage consistently reduced wind erosion on sandy soils in northwestern Ohio, they also stated that excessive amounts of undisturbed crop residues remaining on the surface could reduce soil temperatures, resulting in reduced corn yields on poorly drained dark sandy loam soils.

Table 4.--Effects of tillage and no-tillage of cornstalk land on wind erosion in northwestern Ohio.*

Treatment	Residues	Relative soil loss
	$G./m.^2$	G.
	Expt. I - Comparisons of fall and spring plowing and no-tillage	
Fall plow	28	2,605
Spring plow	12	848
No-tillage	560	119
	Expt. II - Comparisons of plowing with normal residues, and disking and no-tillage with normal and double residues	
Plow, normal residue	14	350
Disk, normal residue	54	510
Disk, double residue	176	84
No-till, zero residue	0	304
No-till, normal residue	182	62
No-till, double residue	285	53

* Data from Schmidt and Kroetz (16).

Portable wind-tunnel tests in Ohio and in Wisconsin also showed a distinct advantage for reduced tillage systems to control wind erosion (tables 5 and 6). That advantage was due primarily to the large amounts of protective residues left on the surface by reduced tillage systems, but also partly to the rougher but slightly more moist soil surface and more nonerodible clods on the reduced tillage areas.

Table 5.--Relative wind erodibility of newly planted cornfields, northwestern Ohio, May 1967.*

Land preparation	Soil type	Soil loss
		Tons/acre
Plowed and planted	Ottokee LFS	180
Power disk and planted	Oakville LFS	3.4
No-tillage and planted	Spinks LFS	0.6
Untilled cornstalk field	Oakville LFS	0.3

* Data from Woodruff et al. (28).

Table 6.--Relative wind erodibility of newly prepared or planted cornland, central Wisconsin, May 1969.*

Land preparation	Soil type	Soil loss
		Tons/acre
Plowed and planted	Plainfield LS	84
Disked and planted	Boone-Hixton LS	28
Plowed and planted - crust broken	Plainfield LS	20
No-tillage and planted	Richford LS	15
Untilled cornstalk field	Plainfield LS	3
Disked winter-killed oats	Plainfield LS	0.8
Standing chemically killed rye	Plainfield LS	0.04

* Data from Woodruff et al. (29).

Moderately severe wind erosion problems on corn and soybean land in Iowa in recent years prompted Moldenhauer and Duncan (13) and Duncan and Moldenhauer (6) to analyze the problem and recommend ways to reduce tillage. One of their primary recommendations was to stop all fall plowing of soybean and corn land, leaving the residues intact for protection from wind erosion. As an alternative, if there must be fall plowing they recommended strip plowing in an unplowed-to-plowed ratio of 1 to 4 or 5, or in actual practice leaving 8 rows of corn or sorghum residue for each 40 rows plowed. They also recommended double disking in the spring and using one of several no-tillage systems commonly used in Iowa. Refuting the idea that fall plowing is necessary to maintain high yields, they gave data to show that corn yields from disked, fall-plowed, and spring-plowed land are almost equal.

Minimum-tillage systems also have been found effective in reducing wind erosion in Illinois and Michigan. Kuder (12) and Oschwald (14) reported widespread acceptance of conservation tillage practices in Illinois to reduce production costs as well as control wind erosion. Approximately 4 million acres were prepared by some form of conservation tillage in 1968 in 60 Illinois counties. Fall chiseling is replacing fall plowing, particularly on soybean land, and has provided more erosion-resistant surfaces. Drullinger (5) has reported that any kind of tillage that leaves residues on the surface is a proven method of wind-erosion control in Michigan. However, he indicated that despite the acknowledged benefits for wind-erosion control, Michigan farmers will be slow to adopt mulch tillage until research shows that the residues will not reduce crop yields. Drullinger also reported some development of specialized tillage equipment such as rigging planters to seed small grain between rows of carrots and special chopping attachments on flexible shafts to remove small-grain rows after they have provided wind-erosion protection for young carrots.

In the Central Great Plains at the Fort Hays Experiment Station, W. M. Phillips has developed effective, combined, tillage-herbicide systems for producing sorghum in a wheat-sorghum-fallow rotation. Herbicides replace three to five tillage operations between wheat harvest and sorghum establishment, thus reducing production costs and residue destruction and providing better wind-erosion control and moisture conservation. Phillips' work will be reported at this Symposium.

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